ADDENDUM TO: APPLICATIONS OF EVALUATED NUCLEAR DATA IN THE LAHET^{TM} CODE

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1 Introduction

This document is intended to provide additional information supplementing reference [1]. The discussion describes the details of the implementation of the proton nonelastic cross section parameterization[2] for LAHET^{TM} usage. It also documents extensions of the method to stable nuclei with $2 \leq \mathrm{Z} \leq 5$.

2 Equations of the Parameterization

As noted in reference [1], the equations quoted in [2] are incorrect. However, a corrected set[3] was obtained, implemented, and verified. The actual equations used to produce the proton nonelastic cross sections for isotopes with $\mathrm{Z} \geq 6$ are the following.

$E \equiv$ incident proton energy (GeV)

$$r_0 = 1.36$$

$$b_0 = 2.247 - 0.915(1 - A^{-1/3})$$

$$s_0 = 10\pi {r_0}^2(1 + A^{1/3} - b_0(1 - A^{-1/3}))$$

$$\sigma_0 = s_0 \ln(A - Z)\frac{1 - 0.15e^{-E}}{1 - 0.0007A}$$

$$p_1 = 8(1 - A^{-1} - 0.001A)$$

$$p_2 = 2(1.17 - 2.7A^{-1} - 0.0014A)$$

$$p_3 = 0.8 + 18A^{-1} - 0.002A$$

$$p_4 = 8(0.7 - 0.002A)$$

$$p_5 = 1.37(1 + A^{-1})$$

$$F_1 = \frac{1}{1 + \exp\{-p_1(\log_{10} E + p_2)\}}$$

$$F_2 = 1 + p_3 \left(1 - \frac{1}{1 + \exp\{-p_4(\log_{10} E + p_4)\}}\right)$$

$$\sigma = \sigma_0 F_1 F_2 \ \text{(millibarns)}$$

3 Modifications for $2 \leq \mathrm{Z} \leq 5$

For $\mathrm{Z} \leq 5$, the proton nonelastic cross sections obtained from the above parameterization diverge greatly from the data of reference [4]. To extend the range of the method to lighter isotopes, the the adjustments shown in Table 1 are applied.

Z	A	σ_0	p_1	p_2	p_3	p_4	p_5
5	-	σ_0	p_1	$p_2 + 0.3$	$2p_3$	$0.8p_4$	$p_5 + 0.3$
4	-	σ_0	$0.7p_1$	$p_2 + 0.25$	$7.5p_3$	$0.6p_4$	$p_5 + 0.7$
3	7	$1.1\sigma_0$	$0.7p_1$	$p_2 + 0.3$	$8p_3$	$0.65p_4$	$p_5 + 0.65$
3	6	$1.3\sigma_0$	$0.7p_1$	$p_2 + 0.3$	$12p_3$	$0.8p_4$	$p_5 + 0.5$
2	4	$1.25\sigma_0$	$2.3p_1$	$p_2 + 0.55$	$4p_3$	$0.65p_4$	$p_5 + 0.7$
2	3	σ_0	$2p_1$	$p_2 + 0.9$	$4p_3$	$0.65p_4$	$p_5 + 0.7$

Table 1: Parameter modifications for $2 \leq \mathrm{Z} \leq 5$

These adjustments were obtained rather quickly by an entirely empirical, trial-and-error method. The resulting cross sections are shown in Figure 1, along with the data used to obtain the fit. The comparison is good, except for $\mathrm{Z} = 2$ which shows need for improvement.

4 Maximum Proton Nonelastic Cross Sections

The tracking algorithm used in LAHET requires the use of some energy independent $\sigma_{max}(A, Z)$ such that

$$\sigma_{max}(A, Z) > \sigma(A, Z, E)$$

for all energies. The following approximation was found that satisfies the need without introducing unnecessary inefficiency into the transport process for protons.

$$\sigma_{max} = s_0 \ln(A - Z)(1 + 2A^{-1} - 0.0026A)$$

where s_0 is calculated as in Section 2. This expression applies for all nuclei with Z $\geq$ 6.

References

[1] R.E. Prael and M.B. Chadwick, "Applications of Evaluated Nuclear Data in the LAHET Code", LA-UR-97-1744, Los Alamos National Laboratory (May 1997), submitted to International Conference on Nuclear Data for Science and Technology, May 19-24, 1997, Trieste, Italy.

[2] H.P. Wellisch and D. Axen, Phys. Rev. C **54**, 1329 (1996).

[3] H.P. Wellisch, private communication to MBC (1996).

[4] B.C. Barashenkov, Cross Sections of Interactions of Particle and Nuclei with Nuclei, JINR, Dubna, 1993 (Available from the NEA Data Bank at http://www.nea.fr/html/dbdata/bara.html).

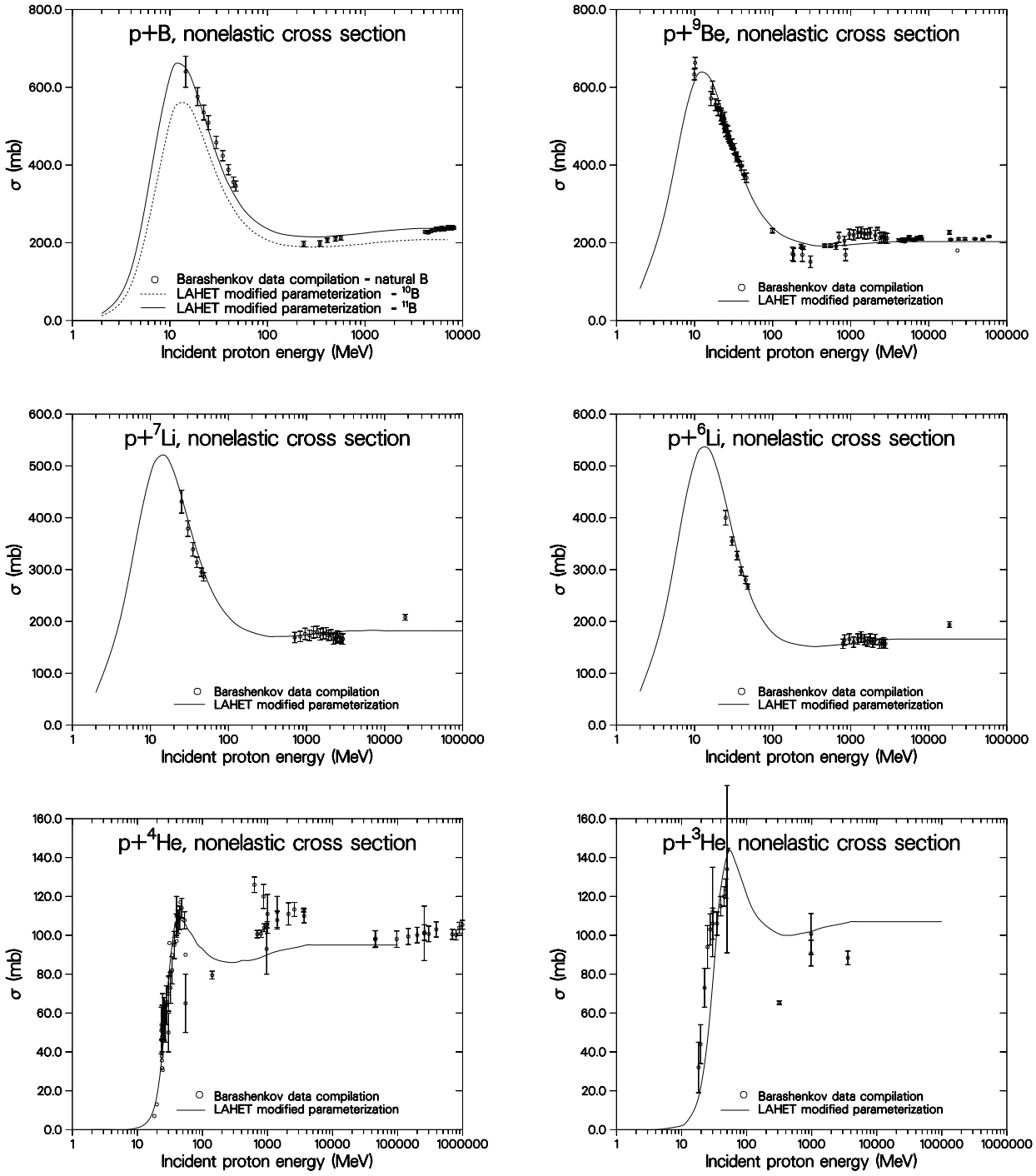

Figure 1: LAHET parameterization of proton nonelastic cross sections for light isotopes compared with the Barashenkov data compilation[4].